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Ergonomic exposure on a drilling rig

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Publication date:
2006

Document Version
Publisher's PDF, also known as Version of record

[Link to publication](#)

Citation for pulished version (APA):
Jensen, C., & Jensen, C. (2006). Ergonomic exposure on a drilling rig. Esbjerg: The Research Unit of Maritime Medicine.

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Ergonomic Exposure Assessment on a Drilling Rig

No. 12 • November 2006



Maritime Occupational Health Publications

The Research Unit of Maritime Medicine (RUMM, University of Southern Denmark) and the Department of Occupational health (AMA) of Ribe County Hospital (SVS) have been collaborating since September 2000 on publishing a series of maritime occupational health reports. Relations were further strengthened in 2003 with RUMM and AMA moving to SVS's facilities in Østergade, Esbjerg.

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The Occupational Department at the Ribe County Hospital in Esbjerg is organized as an independent unit with its own budget, like other departments of the hospital, although it provides specialist occupational health services for Ribe County. The overall aim of the unit is to prevent occupational disease by helping remove or reduce harmful occupational impacts on health, and the consequences of disease, especially on ability to work. ANA is concerned with the link between work and the working environment and health studies by way of examinations on patients, training and research.

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The Research Unit of Maritime Medicine was previously the institute of Maritime Medicine which became an institute of the Esbjerg University Centre in January 1992. In a reorganization in January 2000, it became an independent unit associated with the University of Southern Denmark. RUMM's mission is to provide expertise in developing and ensuring the best possible health, safety and working environment for seafarers, fishermen and offshore employees. RUMM has legislative obligations with the State providing regular funding, set at DKK 2.6 mio. since January 2003. Applications for external funding are made for specific projects.

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ISSN 1600-5988

ISBN 87-90866-13-4

Photo: Roustabouts on a drilling rig.
Private photo.

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Carsten Jensen
Chris Jensen

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Contents

1.0 INTRODUCTION AND AIM.....	3
1.1 BACKGROUND.....	3
1.2 THE PROJECT.....	4
2.0 METHODS.....	5
2.1 ERGONOMIC POSTURE ANALYSIS AND MANUAL HANDLING (PATH).....	5
2.2 INTEROBSERVER AGREEMENT	7
2.3 ANALYSES OF LIFTING TASKS (NIOSH LIFTING EQUATION).....	12
2.4 RECOMMENDATIONS	14
3.0 RESULTS	15
3.1 DERRICK MAN	15
3.2 DRILLER.....	19
3.3 FLOORHAND	23
3.4 ROUSTABOUT.....	27
3.5 (ASS.) CRANE OPERATOR	30
3.6 SCO.....	31
3.7 STEWARD, COOK AND CAMP BOSS.....	33
3.8 TOTAL JOB EXPOSURE	39
4.0 REFERENCES	42

1.0 Introduction and aim

1.1 Background

The offshore oil and gas industry is characterized by a constant focus on safety at work in order to reduce the number of work-related accidents. In companies, the management systems and commitment, which include safety courses for all personnel, formal safety procedures, work permits, near-miss reports and published statistics on lost time injuries, have contributed positively to prevent work-related accidents. The authorities have a similar focus on safety at work offshore. These efforts have resulted in a relatively low frequency of injuries causing absence from work compared to many onshore industries. For instance, in 2004 the frequency of lost time injuries on offshore installations in the Danish Sector of the North Sea was 7 per million working hours. Onshore, the frequency was 36 for shipyards and 20 per million working hours for construction work (Danish Energy Authority 2005).

However, absence from work due to other health problems may not show a similar trend towards lower absenteeism. Sickness absence was reported by Maersk Contractors to have increased among their drilling rig personnel in the Danish Sector of the North Sea from 2000 to 2004 (Steffensen 2005). Their statistics were based on sick leave reported by the personnel during their home period. It was not possible to conclude whether these health problems were related to conditions at work. Clearly, infectious diseases, spare time injuries and a number of other health problems have no association with working conditions, but for some of the most frequent problems, such as musculoskeletal problems, it is difficult to determine whether the causes are work-related or not.

As manual handling (lifting, pushing, etc.) in awkward body postures increase the risk of developing musculoskeletal disorders, it should be expected that work-related health problems contribute to sickness absence in the offshore industry, if these working postures are common. However, also work-related psychosocial factors, personal factors and other factors may contribute to the development of lower back disorders, which often have a multifactorial background. In a relatively old study on American drilling rigs it was indicated that lower back problems was a frequent cause of absence (Clemmer et al. 1991). Most of the incidents causing lower back injuries were associated with heavy lifting or pushing/pulling objects by roustabouts, floorhands, derrickmen and welders. In a more recent study based on Norwegian registers of personnel employed in the Norwegian offshore sector, it was also emphasized that musculoskeletal problems are frequent causes of sickness absence (Mehlum and Kjuus 2005). The Norwegian data also indicated that other work-related health problems than acute injuries were much more frequent than lost time accidents. The number of injuries occurring offshore and reported to the Norwegian authorities in 2004 was 351, whereas it was estimated, that there were as many as 2900-4600 cases of sickness absence, certified by a medical doctor, which were at least partly due to work-related health problems. This corresponded to 59.000-94.000 absence days. This indicates that removal of risk factors for developing musculoskeletal disorders at the work place may have an impact on sickness absence. And it is worth noting that removal

of such risk factors may not only reduce the risk of developing health problems, but it may also reduce sickness absence by removing barriers for work resumption of employees with pain or discomfort, who cannot perform heavy manual handling.

1.2 The project

Increasing sickness absenteeism and an increased focus on occupational health issues, also from authorities and clients, were major reasons for the largest Danish drilling company, Maersk Contractors, to initiate a study in collaboration with the Research Unit of Maritime Medicine, Esbjerg, that should reduce the risk of developing lower back and other musculoskeletal disorders on a drilling rig. The study was designed as an intervention project divided in several phases. The initial phase included a survey of ergonomic exposures of all job positions, identification of ergonomic risk factors and suggestion of solutions to eliminate or reduce the risk factors. The second and third phases include selection and implementation of solutions to improve ergonomic exposures. In the last phase the effects of the intervention are studied.

This report presents the results of the first phase, consisting of ergonomic job analyses on the drilling rig. The drilling rig, Maersk Endeavour, was built in the early 1980'ties and represents some of the older drilling rigs in operation in the North Sea. The personnel employed by Maersk Contractors, who work on the rig, consist of several job groups: management/ administration, deck personnel, drilling personnel and engine personnel are the major groups consisting of about 90 employees. Deck, drilling and engine personnel work in 5 crews each working 12 hours per day. The crew works for 2 weeks followed by a 3 weeks home period, except for some of the senior personnel, who works for 3 weeks followed by a 3 weeks home period. One crew consists of 14-15 people. Catering personnel, who are employed by a subcontractor, were also included in the study and consisted of about 15 employees. Other personnel on the rig were not included in the study. They are mainly technical personnel of other subcontractors and the operator, who has contracted the drilling company to drill for oil.

The job analyses were based on observations and recordings of performed work tasks in combination with data from the work place assessments of the company. The Working Environment Management System of Maersk Contractors details the necessary requirements for carrying out work place assessments. These assessments are supported by questionnaires which cover both physical and psychosocial working environment aspects and which all personnel are invited to complete. The present project used the available information in the work place assessments, where all work tasks were already described. Furthermore, work place assessments of ergonomic working environment exposures based on questionnaires were collected during the course of the project in addition to the job analyses carried out by the Research Unit of Maritime Medicine.

One of the aims of the intervention project is to improve ergonomic exposures on the rig through technical or other improvements and reduce sickness absence in particular related to lower back problems. If possible, the results can also be used to improve the design of new rigs. An evaluation of the interventions is planned to take place later based on new job analyses and sick leave statistics.

2.0 Methods

Two different approaches were used to evaluate ergonomic exposure. One of the methods was a modified version of the PATH-method (Posture, Activity, Tools and Handling), which is a work sampling-based approach (Buchholz et al. 1996; 2003). This method is suited to estimate the fraction of the work time spent in different postures and used for assessing manual handling during specific work tasks. The other method aimed to analyze specific lifting tasks based on the revised NIOSH (National Institute of Occupational Safety and Health, USA) equation (Waters et al. 1993). This method was developed to estimate the risk of lower back pain associated with manual lifting. Both methods may be used to evaluate the risk of developing lower back pain, as risk factors include long term exposure to awkward postures and occasional exposure to heavy lifting.

2.1 Ergonomic posture analysis and manual handling (PATH)






This method was used to quantify ergonomic exposures of specific work tasks based on observations of workers, while they performed their normal job. Workers were observed for 1-3 hours and digital photos were taken at predetermined intervals, usually every 30 or 60 sec. For some work tasks, which were of relatively short duration, the interval was only 10 sec. The photos taken during an observation period were allocated to specific work tasks, if the worker performed more than one work task during the observations (Table 2.1). The definition of work tasks usually followed the definition used in the management system of the company, where a job position normally consists of 2-10 work tasks. For each work task and worker the photos were analyzed using a checklist to assess postures and manual handling of objects, tools and machines (Table 2.2). The fraction of photos where a specific posture was observed corresponded to the fraction of the work time spent in that posture, when performing this particular work task. The mean result of all workers performing the same work task was defined as the exposure associated with this work task. The method is suited to compare working postures used in different work tasks, and thereby pinpoint work tasks or jobs, which are associated with higher risks of developing pain in muscles and joints as compared to other tasks.




Table 2.1. Series of observations for each job position. Each series of observations consists of one worker performing one work task.






Job position	Series of Observations	Number of digital photos	Mean observation time per series of observations (minutes)
Derrickman	10	218	14
Driller	7	363	52
Floorhand	10	469	47
Roustabout	5	324	44
Catering: cook and steward	5	224	45
SCO, Ass. crane operator and crane operator	Short observations of specific tasks or work stations were made of these job positions, mostly because long periods of sedentary work were considered unnecessary to record digitally.		

Job analysis

Table 2.2. Checklist used for quantification of postures and manual handling using the PATH method.

	Trunk	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
	1. straight, upright.....																				
	2. slightly inclined (forward bent)																				
	3. strongly inclined (forward bent).....																				
	4. twisted																				
	5. laterally bent																				

	Arms	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
	1. both arms below shoulder height.....																				
	2. one arm above shoulder height																				
	3. both arms above shoulder height																				

	Legs	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
	1 sitting																				
	2. standing																				
	3. squatting																				
	4. kneeling with one knee or with both.....																				
	5. walking, moving																				

	Manual handling	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
	1 lift /lower object.....																				
	2. carry object.....																				
	3. push/pull object.....																				
	4. operate hand tool.....																				
	5. hold hand tool.....																				

	Weight	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
	1. very light (up to 3 kg)																				
	2. light (3 to 10 kg).....																				
	3. medium (10-20 kg).....																				
	4. heavy (more than 20 kg).....																				

	Operating machine/tool	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
	1. operate machine (valve, bar, hand grip etc)																				
	2. operate machine/tool with high force exertion... ..																				

2.2 Interobserver agreement

This section on interobserver agreement describes the final selection of variables used in the PATH job analyses. For those not interested in methodological issues this section may be skipped and one can continue directly to the next section describing lifting analyses.

A basic requirement for the use of the variables specified in the checklist for the PATH job analyses is that observations can be performed in a reliable way. Thus, it is essential that different observers agree on the classification of the postures observed on the digital photos. To analyze interobserver agreement most of the photos were observed independently by two observers and the results were compared. The comparisons involved the use of several statistical methods, where Bland-Altman statistics and the Concordance Correlation Coefficient (CCC) are the most important (Lin 1989). All of the statistical procedures were based on the percentage of the observation time that a given posture was observed in a consecutive series of photos constituting one job analysis for one subject. Each observer (OBS 1 and OBS 2) analyzed 37 series of photos, e.g. 5 series of roustabouts, 10 series of derrickmen and so forth. If a specific posture was not observed by any of the two observers during a job analysis, then this posture was not included in the analyses. For instance, a straight upright trunk posture was observed during all job analyses and therefore always included, whereas a twisted trunk posture was observed in 18 job analyses and therefore the analyses of twisted trunk posture only included these 18 job analyses (Table 2.3).

Table 2.3. Descriptive statistics of posture variables in the checklist of the PATH observation method used for interobserver agreement analyses

Body posture	N ^a	OBS 1			OBS 2		
		% of total observer time			% of total observer time		
		Mean	Min	Max	Mean	Min	Max
Straight, upright	37	75	31	100	80	38	100
Slightly inclined	34	17	0	55	12	0	40
Strongly inclined	23	9	1	26	8	0	31
Twisted	18	3	0	14	4	0	9
Laterally bent	23	4	0	20	4	0	22
Both arms below shoulder	37	95	69	100	94	57	100
One arm above shoulder	28	4	0	23	7	0	38
Both arms above shoulder	12	4	0	13	3	0	5
Sitting	12	23	0	70	23	1	71
Standing	37	80	30	100	66	17	100
Squatting	9	7	0	26	10	3	24
Kneeling	5	2	0	4	4	0	10
Walking, moving	28	14	3	46	31	7	80

^a Number of job analyses included in the statistical analyses. Values of 0.0 were excluded.

Bland-Altman statistics is based on the difference between the results of the two observers. The mean difference between OBS 1 and OBS 2 and the 95% limits of agreement (LOA) were calculated (Table 2.). LOA indicate the upper and lower limits, where one should expect 95% of the differences to occur. Thus, when the mean difference is -5% and LOA are -19% and 9%, as it was for an upright trunk posture, this shows that OBS 1 on average classifies jobs as being performed with “upright trunk” for 5% less of the observation time than OBS 2. For 95% of the job analyses performed by these two observers the difference for “upright trunk” will be between -19% and 9% of the observation time. Thus, it also happens that OBS 1 observes more upright postures than OBS 2 in a job analysis, but the opposite situation is more frequent (Fig. 2.1).

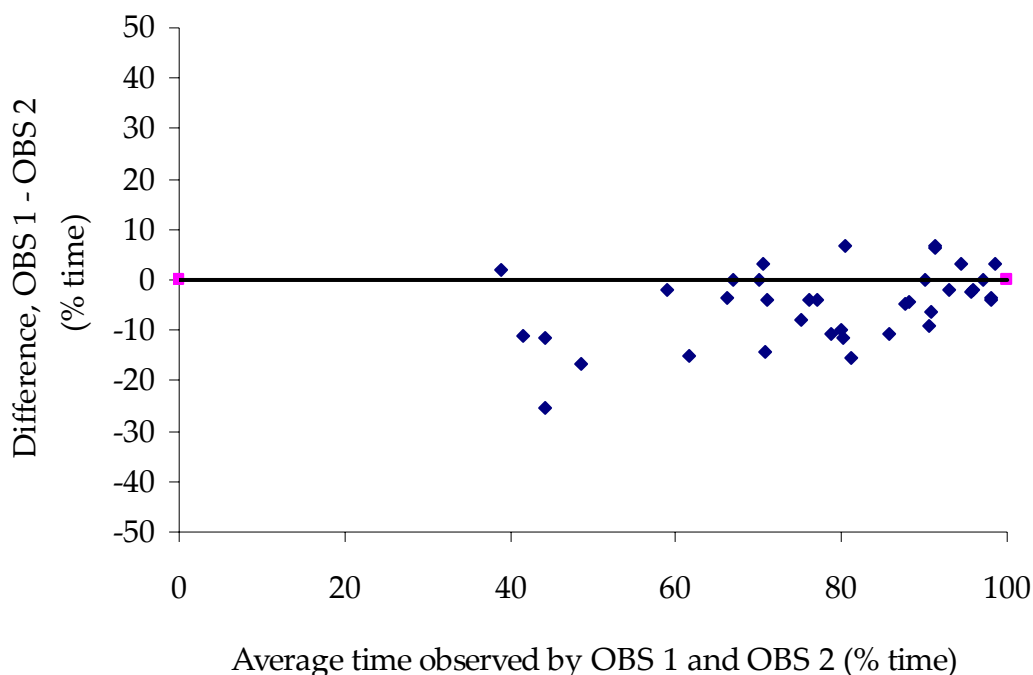


Fig. 2.1. Bland-Altman plot for upright trunk posture (LOA -19;9)

The Concordance Correlation Coefficient (CCC) is a measure of the deviation from the line from 0;0 to 1;1, when the results of OBS 1 and OBS 2 are plotted against each other (Fig. 2.2). If the two observers always obtain the same result, all points in the plot will be on this line, the fit will be perfect and CCC will be 1. Usually the results of the two observers differ somewhat from each other and CCC will be lower than 1. For our purposes we have defined a CCC of at least 0.8 as acceptable. CCC is composed of two other coefficients, the Pearson correlation coefficient and the bias correction factor, which both may range from 0 to 1. Pearsons correlation coefficient describes the correlation between the two observers, but cannot detect a systematic bias between observers. If OBS 1 always observes a posture twice as frequently as OBS 2, Pearsons correlation coefficient will be 1, i.e. corresponding to a perfect correlation, but in this case the bias correction factor will be lower than 1. If no

systematic bias is present, e.g. data are scattered unsystematically around the line from 0.0 to 100.100, the bias correction factor will be 1, but Pearson's correlation coefficient will be lower than 1. CCC is Pearson's correlation coefficient multiplied with the bias correction factor.

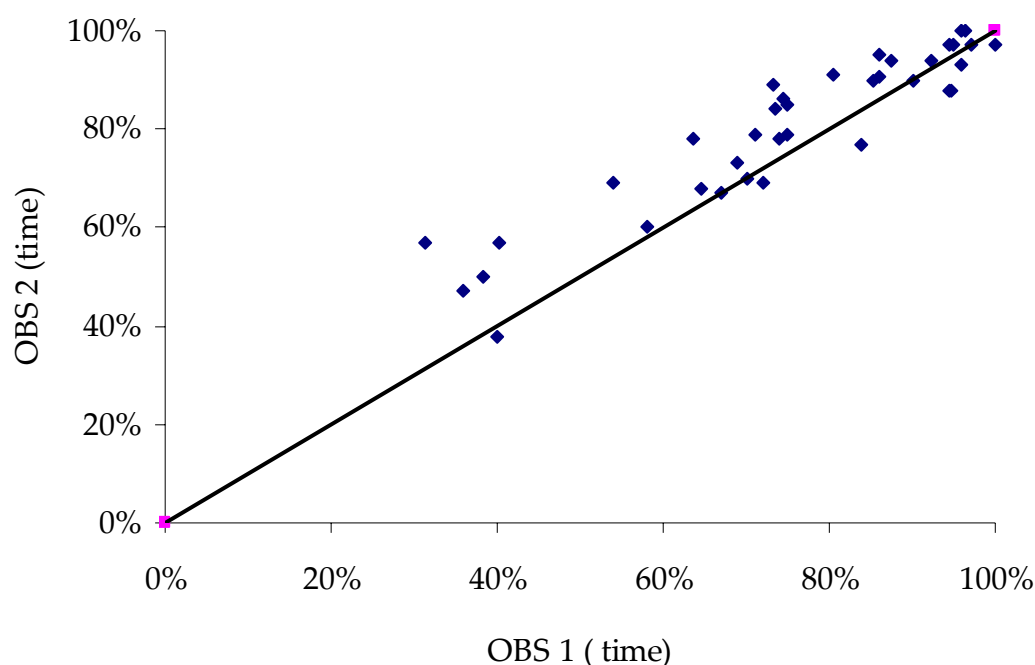


Fig. 2.2. Results of OBS 2 plotted against OBS 1 for upright trunk posture. If data were situated on the straight line between 0.0% and 100.100% (perfect fit), CCC would have been 1. In the actual case, CCC is 0.88.

The results of the interobserver agreement analyses are shown in Table 2.. For trunk postures acceptable concordance was obtained for upright, slightly forward bent and strongly forward bent postures. For twisted and laterally bent trunk postures the concordance was not acceptable as CCC was below 0.8. The main explanation for this was that these two postures were seldom observed (on average 3-4% of the observation time). When only small differences in exposure are observed between different jobs, it becomes difficult to establish, whether these results are reliable. Furthermore, it was sometimes difficult to judge whether a posture should be categorized as twisted or laterally bent as both postures could occur at the same time. Therefore, it was decided to collapse the variables "strongly forward bent", "twisted" and "laterally bent" into one exposure category. All three exposures should be considered high risk exposures for lower back pain, and the new variable would indicate the highest risk of the remaining three variables categorizing trunk posture. The mean difference between observers for the new variable "strongly forward bent, twisted or laterally bent" was 0% of the observation time and CCC was acceptable (0.93, Table). It was tempting to collapse also "upright trunk" and "slightly forward bent", as a systematic bias between observers was indicated. OBS 1 typically

categorized more postures as slightly forward bent and fewer postures as straight upright as compared to OBS 2. However, the difference was not dramatic, on average 5-6% of the observation time. Also, these two postures represent a difference in risk of developing back pain, so they were retained in the analyses.

Table 2.4. Interobserver agreement of posture variables in the checklist of the PATH observation method

Body posture	Bland Altman statistics (% of total observer time)		Concordance			
	Mean diff. ± SD	95% limits of agreement (LOA)	Pear- sons R	Bias cor- rection factor	CCC ^a	95% C.I. ^b of CCC
Straight, upright	-5 ± 7	-19;9	0.93	0.95	0.88	0.82-0.95
Slightly inclined	6 ± 6	-5;17	0.91	0.89	0.81	0.71-0.91
Strongly inclined	1 ± 4	-7;8	0.92	0.97	0.89	0.81-0.97
Twisted	-1 ± 4	-10;8	0.13	0.86	0.11	-0.31-0.52
Laterally bent	0 ± 3	-6;6	0.80	0.99	0.79	0.63-0.95
Arms below shoulder	1 ± 4	-7;10	0.85	0.96	0.81	0.71-0.92
Arm above shoulder	-2 ± 4	-11;7	0.82	0.88	0.72	0.57-0.87
Arms above shoulder	1 ± 4	-6;8	0.37	0.67	0.24	-0.13-0.62
Sitting	-1 ± 1	-3;2	1.00	1.00	1.00	1.00-1.00
Standing	14 ± 15	-15;43	0.75	0.77	0.57	0.40-0.74
Squatting	-3 ± 3	-9;4	0.95	0.92	0.88	0.74-1.00
Kneeling	-2 ± 5	-11;7	-0.39	0.61	-0.24	-0.90-0.43
Walking, moving	-17 ± 15	-46;12	0.58	0.49	0.28	0.11-0.46

^a Concordance correlation coefficient

^b Confidence interval

When assessing arm postures it could be difficult to judge, whether the arms were raised above shoulder height, if the trunk was forward bent at the same time. As for the high risk trunk exposures, it seldom occurred that work was performed with arms raised above shoulder height. Again, the lack of exposure contrast between jobs produced low CCC's even though the mean difference between the two observers was small (1% of the observation time). Thus, the categories "one arm above shoulders" and "two arms above shoulders" were collapsed into one variable in the further analyses, but high CCC's were not reached due to the low exposure contrast, which was still present (i.e. working with both arms below shoulder height usually occurred for more than 90% of the observation time, Table 2.6).

For leg postures, the category "sitting" was easy to observe and the agreement between observers almost perfect. "Standing" and "walking" was difficult to distinguish from still photos, the differences between observers were large and CCC was low. This left no other choice than collapsing these two variables. The new variable "standing or walking" was characterized by a mean difference between observers of 1% and a CCC of 0.99, that is, a very high interobserver agreement (Table). Acceptable interobserver agreement was also found for "squatting", but not for "kneeling", again due to the seldom occurrence of this

posture. Consequently, these two postures, which represent an elevated risk for knee and hip problems, were collapsed in the further analyses. The variable “squatting or kneeling” was characterized by acceptable interobserver agreement.

Table 2.5. Descriptive statistics of final variables of the PATH observation method used for interobserver agreement analyses (% of total observer time)

Body posture	OBS 1				OBS 2		
	N ^a	Mean	Min	Max	Mean	Min	Max
Straight, upright	37	75	31	100	80	38	100
Slightly inclined	34	17	0	55	12	0	40
Strongly inclined, twisted or laterally bent	33	10	0	40	10	0	31
Both arms below shoulder	37	95	69	100	94	57	100
One or both arms above shoulder	28	6	0	31	8	0	43
Sitting	12	23	0	70	23	1	71
Standing or walking	37	91	30	100	90	27	100
Squatting or kneeling	12	6	0	26	9	0	34

^a Values 0.0 excluded from analyses

Table 2.6. Interobserver agreement for final variables of the PATH observation method.

Body posture	Bland Altman statistics (% of total observer time)		Concordance			
	Mean diff. ± SD	95% LOA	Pearsons R	Bias correction factor	CCC ^a	95% C.I. ^b of CCC
Straight, upright	-5 ± 7	-19;9	0.93	0.95	0.88	0.82-0.95
Slightly inclined	6 ± 6	-5;17	0.91	0.89	0.81	0.71-0.91
Strongly inclined, twisted or laterally bent	0 ± 4	-7;7	0.93	1.00	0.93	0.88-0.98
Both arms below shoulder	1 ± 4	-7;10	0.85	0.96	0.81	0.71-0.92
One or both arms above shoulder	-1 ± 5	-11;8	0.81	0.95	0.77	0.63-0.92
Sitting	-1 ± 1	-3;2	1.00	1.00	1.00	1.00-1.00
Standing or walking	1 ± 2	-3;8	0.99	1.00	0.99	0.98-1.00
Squatting or kneeling	-3 ± 4	-10;4	0.93	0.94	0.88	0.75-1.00

^a Concordance Correlation Coefficient

^b Confidence interval

2.3 Analyses of lifting tasks (NIOSH lifting equation)

This analysis produces an index, which indicates the risk of developing lower back pain (LBP) associated with manual lifting. The lifting index values should be interpreted as guidelines. They may be used to identify lifting tasks with higher risk levels relative to other lifting task, as no exact value of the lifting index exists, that always distinguishes no-risk tasks from high risk tasks (Waters et al. 1998; 1999, van der Beek et al. 2005). An advantage of the analysis is, that it may be used to show the effect of several factors besides the weight of the lifted object. Thus, both symmetrical and asymmetrical two-handed lifting tasks and lifts of objects with less than optimal couplings between the object and the worker's hands can be analyzed. To perform the analyses, specific lifting activities were video recorded to capture the situation, where the highest loads on the lower back occurred during the lift.

Two values were calculated; the *Recommended Weight Limit (RWL)* and the *Lifting index (LI)*. The RWL is defined for at specific set of task conditions as the weight of the load that nearly all healthy workers can perform without an increased risk of developing lifting-related LBP. The factors used for calculating RWL are: *the weight of the object, horizontal and vertical position of the object, angle of trunk twist, frequency of lift, duration of lift and object coupling*

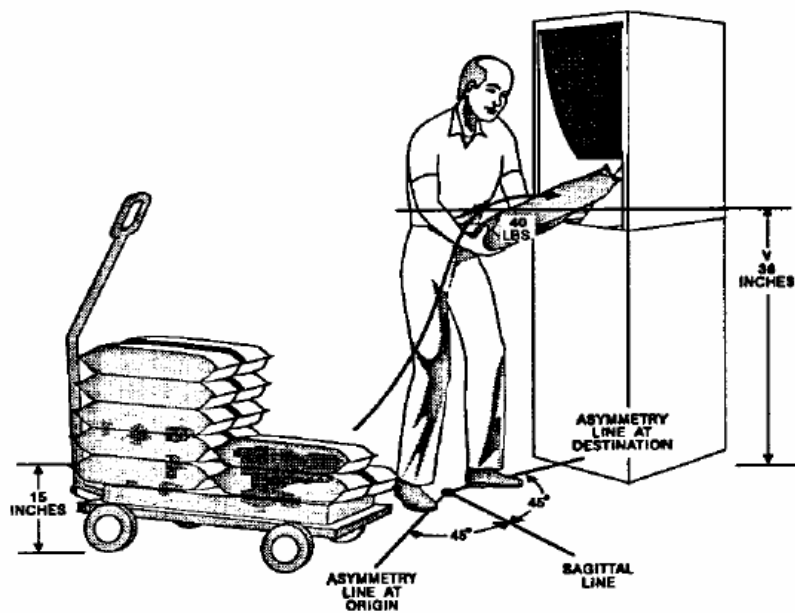
The LI is the term that provides a relative estimate of the level of ergonomic stress associated with that particular lifting task. The estimate is defined by the relationship of the weight of the object lifted and the calculated RWL.

$$LI = \frac{L}{RWL}, \text{ where (L) is the weight (load) of the object}$$

Values of LI below 1 indicate no increased risk of lower back pain, values between 1 and 2 indicate medium increased risk of lower back pain and values above 2 indicate highly increased risk. In other words, as the magnitude of the LI increases, (1) the level of the risk for a given worker would be increased, and (2) a greater percentage of the workforce is likely to be at risk for developing LBP. The goal should therefore be to design lifting jobs so that the LI is 1.0 or less.

For instance, during mud mixing sacs with a weight of 25 kg are manually lifted from a table to the sack cutter. The RWL was calculated to 20 kg. The actual load was above the recommended load and the lifting index was $25/20 = 1.25$.

For lifting tasks with variability in one or more factors, such as those in which the vertical height or horizontal distance varied from lift to lift, a minimum and maximum LI was computed for a worst-case and best-case assessment. Furthermore, the calculations were based on averages taken across all samples for each lifting job.



JOB ANALYSIS WORKSHEET											
DEPARTMENT		<u>Manufacturing</u>					JOB DESCRIPTION				
JOB TITLE		<u>Batch Processor</u>					<u>Dumping bags into mixing</u>				
ANALYST'S NAME							<u>hopper</u>				
DATE							<u>Example 3</u>				
STEP 1. Measure and record task variables											
Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate	Duration	Object Coupling
L (AVG.)	L (Max.)	H	V	H	V	D	Origin	Destination	Lifts/min	(HRS)	C
40	40	18	15	10	36	21	45	45	<.2	<.1	Fair
STEP 2. Determine the multipliers and compute the RWL's											
RWL = LC × HM × VM × DM × AM × FM × CM											
ORIGIN		RWL = <input type="text" value="51"/> × <input type="text" value=".56"/> × <input type="text" value=".89"/> × <input type="text" value=".91"/> × <input type="text" value=".86"/> × <input type="text" value="1.0"/> × <input type="text" value=".95"/> =						18.9 Lbs			
DESTINATION		RWL = <input type="text" value="51"/> × <input type="text"/> × <input type="text"/> × <input type="text"/> × <input type="text"/> × <input type="text"/> × <input type="text"/> =						Lbs			
STEP 3. Compute the LIFTING INDEX											
ORIGIN		LIFTING INDEX =		OBJECT WEIGHT (L)				=		40	
				RWL				=		18.9	
										2.1	
DESTINATION		LIFTING INDEX =		OBJECT WEIGHT (L)				=			
				RWL				=			
											

Fig. 2.3. Example of model and original worksheet used in the NIOSH lifting analysis (Waters et al. 1998; 1999)

2.4 Recommendations

Recommendations for improvements were based on the results of the job analyses and suggestions by the personnel. Thus, while the job analyses were used to conduct risk assessments as objectively as possible, the personnel was believed to be the frontline experts on their own job tasks and would therefore provide the best suggestions for improvements. When performing the observations on the rig, the personnel were encouraged to suggest improvements, which were noted and written in this report, if the solutions could be expected to improve the ergonomic exposure of the “high risk” work tasks. Often the solutions were based on the employees’ experiences from other rigs or simply from everyday experiences with troublesome working techniques. In some cases it was recommended to improve the ergonomic exposure of a specific task without providing a direct solution, especially if solutions were considered to require considerable assistance from engineers. All recommendations were based on ergonomic criteria only. Other criteria will be relevant to consider by the company (or the relevant subcontractor) before implementing some of the solutions, such as safety related criteria, expected cost-benefit or other issues that are not included in the present report.

3.0 Results

3.1 Derrick Man

Workarea: Drilling

Sub areas: Pump room, pit room, mud lab, hopper area and sack store

During drilling the derrick man mix and maintains mud below deck. Chemicals used for mud mixing are stored in the sack store and he transfers these chemicals to the hopper area, when mud is mixed. The contents of sacks and barrels are poured into the sack cutter, and the mud is transferred for storage in the pit room. From here the mud is continuously pumped out to the drill pipe system. In the mud lab the derrick man weighs mud samples and writes reports. All working areas are situated next to each other, however, partly at different floor levels.

3.1.1 Postures and manual handling

Four derrick men were observed. Fig. 3.1 shows trunk and leg postures for 4 work tasks. Risk factors for lower back pain include twisted, forward and laterally bent trunk postures. For derrick men these postures were mainly registered in the pump room, where less than 40% of the time was spent in an upright trunk posture.

Knee and hip problems may be associated with squatting, kneeling, prolonged standing or walking at work. Considerable squatting occurs in the pump room only. In general, much of the work time was spent standing or walking. As the pump room and sack store are located one floor down as compared to the other sub areas, some of the walking takes place on stair cases. On average each derrick man working below deck walks 1000-1500 steps up or down stairs during a 12 hour shift. A few times stairs are walked with a load of up to 25 kg.

A known risk factor for shoulder pain is work with arms elevated above shoulder height, however, this was only observed for 3% of the work time (Fig. 3.2).

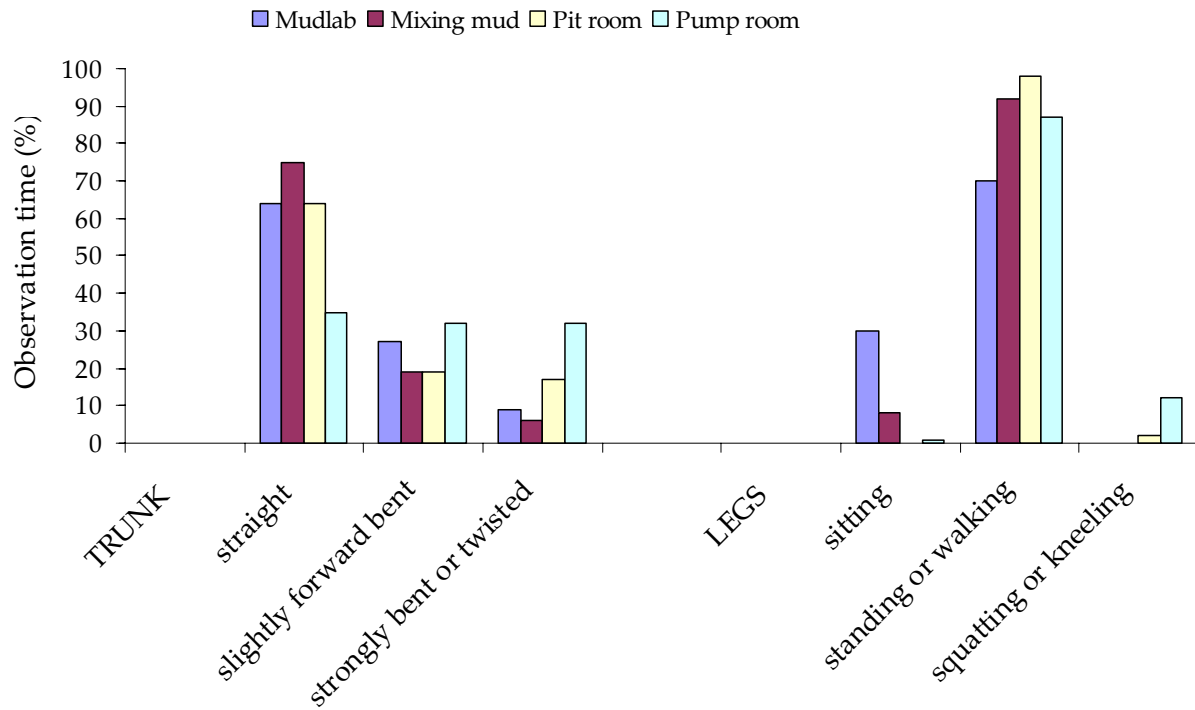


Fig. 3.1. Relative time spent in different trunk and leg postures

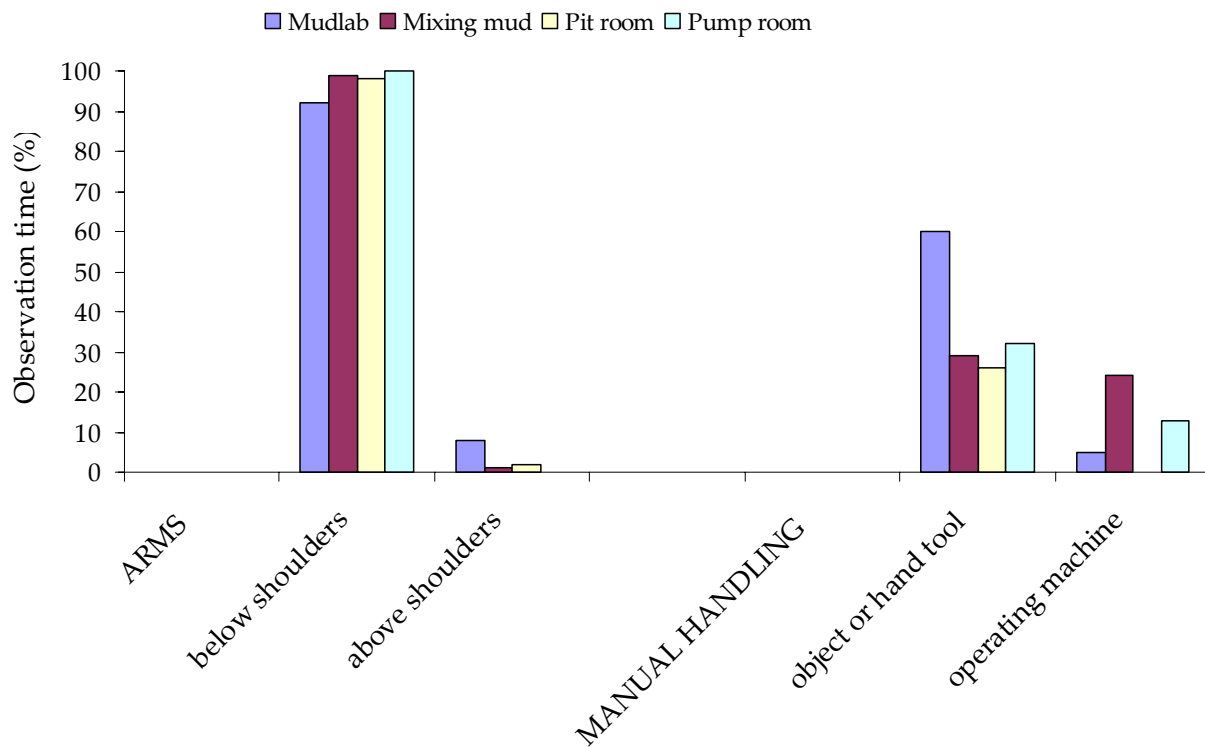


Fig. 3.2. Relative time spent in different arm postures and performing manual handling

Thus, the posture analyses pointed towards work in the pump room as the sub area, where awkward postures occur most frequently. However, the total time spent in the pump room was shorter than in any of the other sub areas (approx. 10% of the work time for routine maintenance). Longer work periods in the pump room do occur when the pumps need repair, but the time spent for unforeseen events is difficult to estimate here. Handling objects, tools or operating machines generally occur in all sub areas (Fig. 3.2). For most of the time the objects handled are light (weighing mud, carrying cans with mud or oil, writing reports). One exception is handling of sacks or barrels with chemicals for mixing mud in the hopper area. The time spent lifting heavy objects is short compared to the total work time and these lifting tasks at the sack cutter were therefore analyzed separately with the NIOSH lifting equation.

3.1.2 Manual lifting

A summary of the results of the lifting analyses during mud mixing in the hopper area is provided in Table 3.1. The lifting tasks pose a medium risk of LBP as LI values are within 1-2. Use of adjustable table or forklift is recommended (and already in use) as the lifting index increases with lift from floor level (1,5) or lift performed with twisted trunk (1,6). The recommended sack weight should not exceed 20 kg when lifts are performed using the adjustable table, whereas the load should not exceed 15 kg if they had been lifted from floor level.

Table 3.1. Lifting equation values for the derrick man working in hopper area

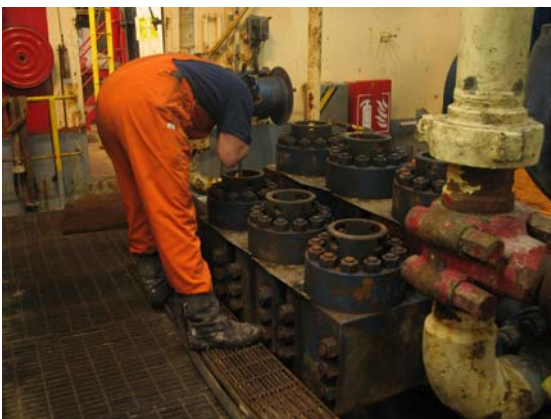
	Recommended Weight Limit (kg)		Lifting index	
	Origin (floor or table)	Destination (sack cutter)	Origin	Destination
Sack lifting^a	21 kg	23 kg	1,2	1,1
Sack lifting^b	17 kg	20 kg	1,5	1,2
Sack lifting twisted^c	15 kg	20 kg	1,6	1,2

^a Sacks lifted from adjustable table to sack cutter (vertical distance 20 cm)

^b Sacks lifted from floor level to sack cutter (vertical distance 85 cm)

^c Sacks lifted from floor level to sack cutter with twisted trunk (45 deg.).

A



B



Fig. 3.3. In the pump room awkward postures are common (A). Hopper area, where sacks are handled manually (B).

3.1.3 Conclusions

The pumps are ergonomically not well designed and most operations to maintain pumping activity are performed with awkward postures. Thus, the pump room is the area, where awkward postures occur most frequently.

The pit room is ergonomically well designed. Most handles are placed at hip height and there is enough space between devices.

In the hopper area the peak loads on the lower back at the sack cutter impose a medium risk of developing lower back pain,

Considerable walking on stairs imposes stress on knees and legs.

3.1.4 Suggestions for improvements

- **Mud lab:** Weighing mud is usually performed with a slightly forward bent trunk posture. This is a minor problem, which could be improved by increasing the table height.
- **Pump room:** The best advice to avoid awkward postures is to work as little as possible in the pump room. This is easy to follow during routine work days, but major repairs should increase awareness of taking turns for each other.
- **Hopper area/pit room:** Some of the stress on knees and legs can be reduced by using the forklift to handle loads and by making access to the hopper area from the pit room, if possible.
- **Hopper area:** Strain on the lower back during lifting could be reduced by one of the following improvements:
 - Replace existing cutter with a more modern version, where the sacks are pushed from a conveyor belt into the sack cutter.
 - Reduce the weight of each sack from 25 to 20 kg.
 - Have the chemicals delivered in containers, from which the chemicals can be transferred to the mixer by pumps or other automated systems.

3.2 Driller

Work area: Drillers cabin
Work tasks: Drilling, tripping operations

During drilling the driller operates the drilling equipment and related systems. At the same time he supervises the drill crew. The drillers work task may be divided in two different main processes, which both are carried out for a considerable amount of time in the drillers cabin. One is the actual drilling process, and the other process consists of taking the drill pipe out of the hole or putting pipe or casing into the hole. In this report we refer to the former process as “drilling” and the latter process as “tripping operations”. Together, these two processes constitute almost all of the work performed on a normal shift. Some administrative work is also carried out by the driller, but this constitutes only a smaller part of the work and is not considered in the present analyses.

3.2.1 Postures and manual handling

Figures 3.4 and 3.5 show the time spent in different postures.

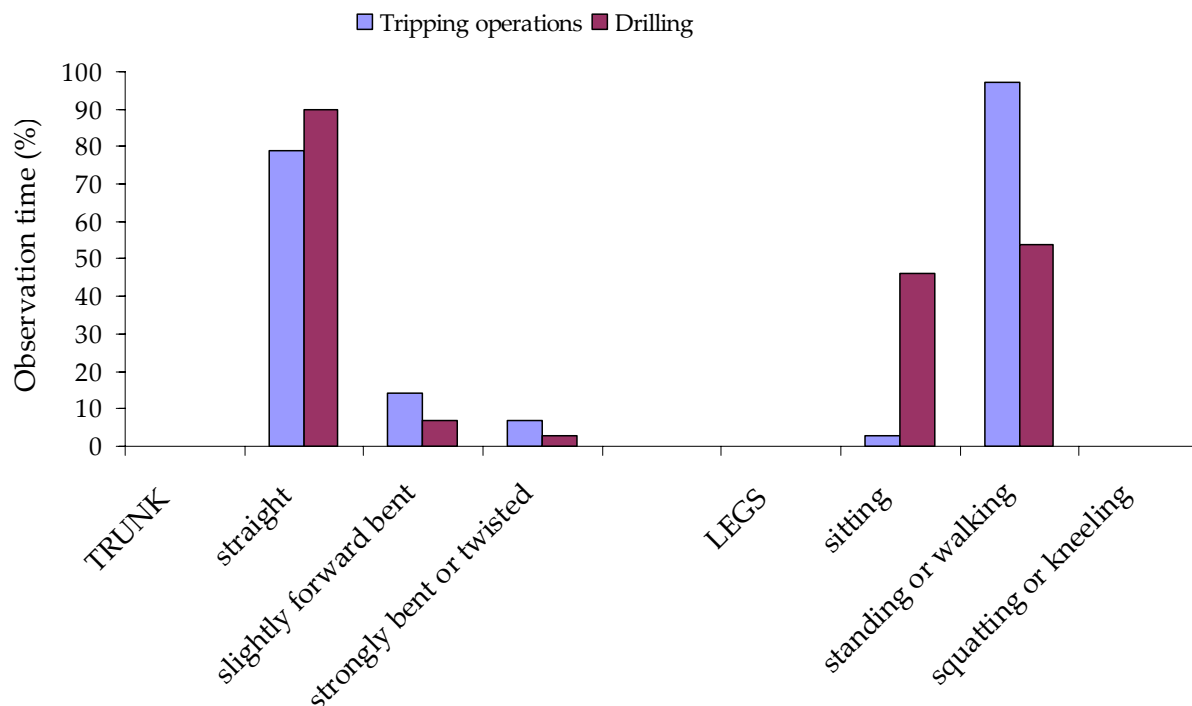


Fig. 3.4. Relative time spent in different trunk and leg postures

For drillers, twisted, forward and laterally bent trunk postures were seldom observed, as 80-90% of the time was spent in an upright or almost upright trunk posture. During tripping operations the trunk was slightly more often in a bent posture than during drilling. Squatting or kneeling was not observed at all. Walking occurred for a small

fraction of the work time. During drilling the driller could often choose to work seated or standing as he would prefer himself, but tripping operations was nearly always performed while standing.

Elevated arms above shoulder height were only observed for 2% of the work time.

In general, the work time spent in different neck postures has not been estimated. However, for the driller a large fraction of the work time was spent with a twisted neck and twisted legs when operating the brake and monitoring display units, which were partly placed in a direction opposite to the drill pipe. Thus, the driller often has to turn his back or the side of his body to the drill pipe, while he still watches the pipe by twisting his neck.

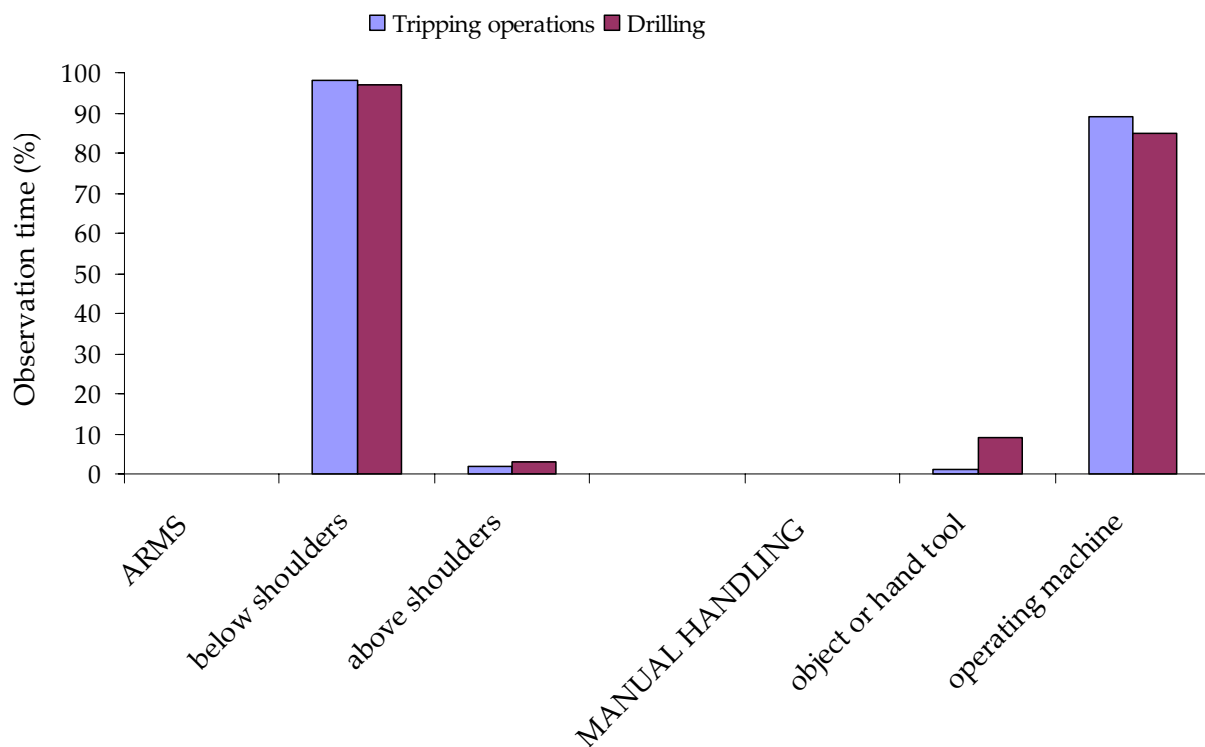


Fig. 3.5. Relative time spent in different arm postures and performing manual handling

Fig. 3.5 shows that 85-89% of the time was spent operating machines, which for the driller is the drilling equipment. The force exertion was usually moderate, but operating the brake requires considerable force exertion for some of the time, especially during tripping operations. During drilling the brake is usually held in the same position for longer periods, which requires less force.

Furthermore, these work processes require a high degree of constant attention, as the driller should both watch the drill pipe, the drill crew and monitor display units. He is unable to leave his position for short breaks if the assistant driller is not present to take over. During tripping operations the attention required was in general higher than during the drilling process.

3.2.2 Conclusions

Extreme postures and high force exertion was not a general problem for the driller. However, the very high proportion of the time spent standing with a high degree of attention, twisting the neck and operating the drilling equipment, in particular the brake during tripping operations, may increase the risk of developing symptoms in muscles and joints.

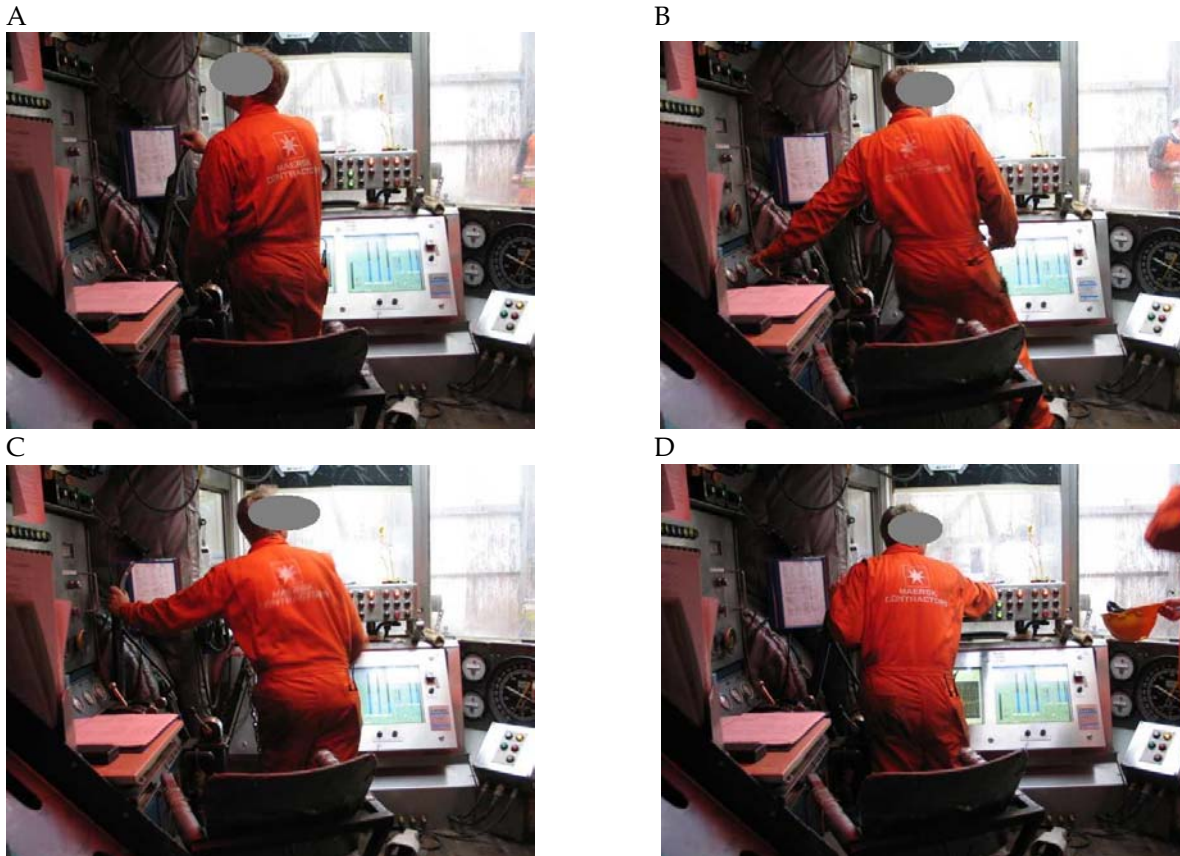


Fig. 3.6. Tripping operations. When the drill pipe is taken up or put into the hole, when new pipes are added or casing is placed in the hole, the driller works in a standing posture handling the brake and other equipment. Continuous attention is needed to perform the task correctly in coordination with the crew outside the cabin.

3.2.3 Suggestions for improvement

- The single most critical element which could be changed to improve ergonomics in the driller's cabin is the brake. Except for the visible part of the brake, the brake handle, it is not possible for us to determine which changes are feasible. This requires assistance from an engineer, but we may point out the following factors: The brake handle is made of solid metal and is relatively heavy. By using a hollow metal handle the force required to operate the handle could be reduced. Alternatively, a device could be installed that could

produce some of the force needed to move the handle and at the same time lock the handle in a fixed position when needed. Furthermore, when seated the driller constantly has to reach the handle with a straight arm. A different handle design should place the handle closer to the chair of the operator. Installing a device that can be operated with both hands would also reduce the static muscle strain and improve the working conditions. Additionally, it should be considered, whether the brake could be redesigned, so that it also may work as a footbrake, such as a pedal on the floor working like a reversed spring brake. In order to loosen the brake the driller would have to exert downward force on the pedal and press it towards the floor. Removing the foot from the pedal would then apply full braking power to the top drive automatically. If the driller for unforeseen reasons removes the foot off the pedal the top drive would be stopped immediately. However, just as a string is used to apply a constant braking level on the existing brake handle, it would be necessary to be able to lock a foot pedal brake in a fixed position when needed. A foot pedal brake would work fine as a supplement to the redesign suggested above, as it offers variation to the drillers braking operations and thereby may reduce the static muscle strain.

- During daily operations the phone in the driller's cabin is often operated. Apart from the fact that this draws attention away from the drilling floor the phone should be moved. A simple extension cord would solve the problem and the phone should be placed in front of the driller and thereby reduce the neck and body twist.
- A more thorough solution would be to rearrange the entire lay out of brake handle, monitors and other equipment in the driller's cabin. This solution is better, but the improvement of the ergonomic exposure may not be very high compared to a specific improvement of the braking equipment and a rearrangement of a few other elements in the cabin. Modern rigs have modern computerized control rooms where the driller may sit in a chair and operate and monitor most of the work processes. This is clearly better than the drillers cabin on Endeavour, but it should always be kept in mind that static postures are problematic, also if seated for all of the work time. Thus, the ergonomics of more mechanical and manually handled equipment may be just as good or even superior to the entirely computerized work stations, as long as prolonged static muscle activity can be avoided.

3.3 Floorhand

Work area: Drill floor
Work tasks: Drilling, tripping operations

The floorhands handle drilling equipment on the drill floor. Some of the work processes are performed manually and some of them are performed by operating the iron roughneck. Some work processes include operation of the elevator that handles pipes to the drill floor. Drilling may be divided into two processes. One is the actual drilling process, and the other process consists of taking the drill pipe out of the hole or putting pipes or casing into the hole. In this report we refer to the former process as “drilling” and the latter process as “tripping operations”.

3.3.1 Postures and manual handling

Figures 3.7 and 3.8 show the time spent in different postures.

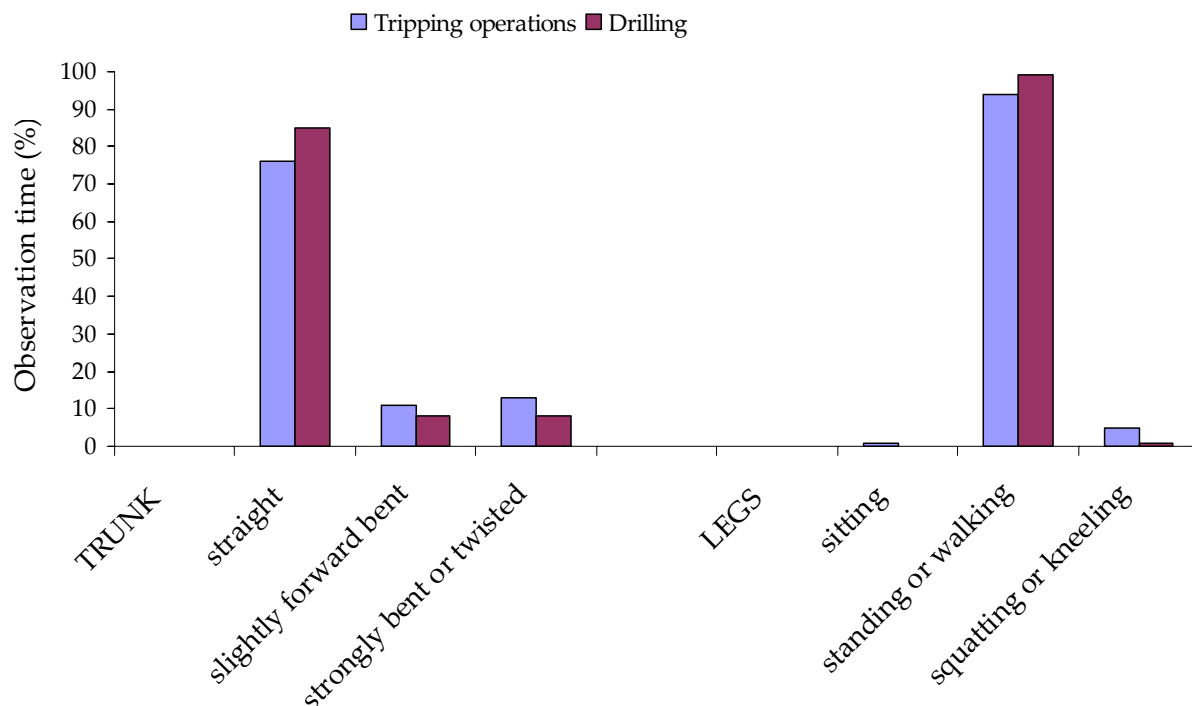


Fig. 3.7. Relative time spent in different trunk and leg postures

Twisted, forward and laterally bent trunk postures were seldom observed. About 80% of the time was spent in an upright or almost upright trunk posture and most of the remaining time the trunk was slightly forward bent. This was similar for both tripping operations and drilling operations. Knee and hip problems may be associated with squatting, kneeling, prolonged standing or walking at work. However, squatting or kneeling was seldom observed. Prolonged standing did occur while waiting for the next

operation, while operating the iron roughneck or while performing other types of manual handling, but should not be considered a serious risk factor as the floorhands in general were free to move around.

Elevated arms above shoulder height were observed for 10% and 3% of the work time for drilling and tripping operations, respectively.

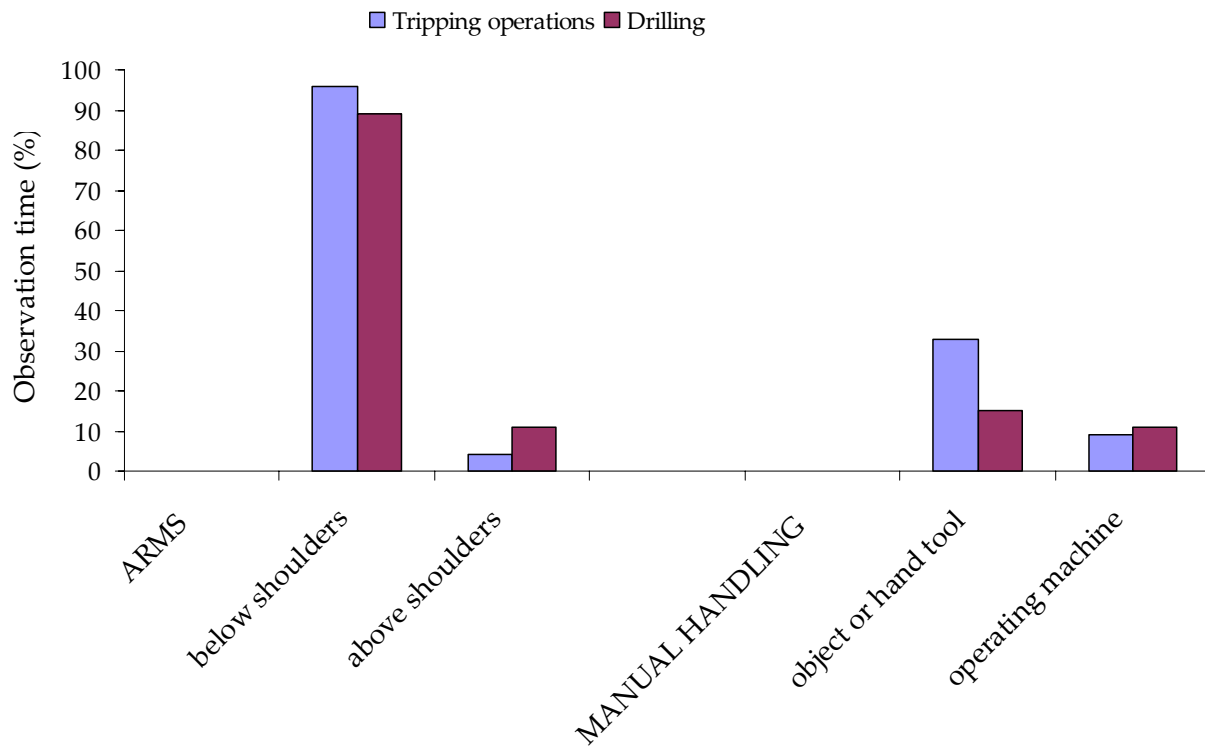


Fig. 3.8. Relative time spent in different arm postures and performing manual handling

Fig. 3.8 shows that 15-33% of the time is spent on manual handling of objects or hand tools. Most of this activity is pushing or pulling objects. Fig. 3.8 also shows that 9-11% of the time is spent operating machines, which for the most part is the iron roughneck using a remote control. The force exertion during manual handling varied from light to very heavy. A few specific processes of short duration required high force exertion, especially the process, which consisted of placing a slip in the pipe hole. Other situations present a risk of developing muscle problems, especially when machine breakdown occurs. This could be the case if the roughneck is out of order for more than a day and the demands of heavy manual handling increase considerably. This has not been observed by us and specific analyses are therefore not possible.

A



B



C



Fig. 3.9. Floorhands have various tasks on the drill floor, such as operating the iron roughneck (A) and connecting or disconnecting equipment (B and C). Awkward postures do occur as exemplified by the photographs, but usually for short periods of time.

3.3.2 Conclusions

Exposure to prolonged awkward postures was not a general problem for the floorhands. Demands of physical activity vary considerably, and it is beneficial for muscles and joints to avoid long periods of fixed working postures or inactivity. However, heavy manual handling does occur and these peak exertions of short duration expose the floorhands to increased risks of musculoskeletal injuries. One example of heavy manual handling is lowering of slips into the pipe hole.

3.3.3 Suggestions for improvement

- Manual lifting and lowering heavy objects into the drilling hole should be avoided if technically possible.
- Machine breakdown (iron roughneck) was not observed during our stay on Endeavour, but is reported by the crew to increase demands of heavy physical handling. The crew should have focus on such episodes and consider solutions that

could reduce physical demands, if normal machine operations are not possible for more than a day. One solution could be to have clear procedures that describe how the personnel must use job rotation during such episodes in order to expose each floorhand to very high force exertions for as short a period as possible.

3.4 Roustabout

Work area: Deck

Work tasks: Pipe handling on deck, container handling and maintenance

For roustabouts the job consists of a number of tasks of which some are insignificant in relation to the ergonomic analysis. The tasks analyzed here were related to handling and preparation of pipes and casing on the deck (incl. attending crane operations), container handling, and cleaning with a high pressure cleaner.

3.4.1 Postures and manual handling

Figures 3.10 and 3.11 show the time spent in different postures.

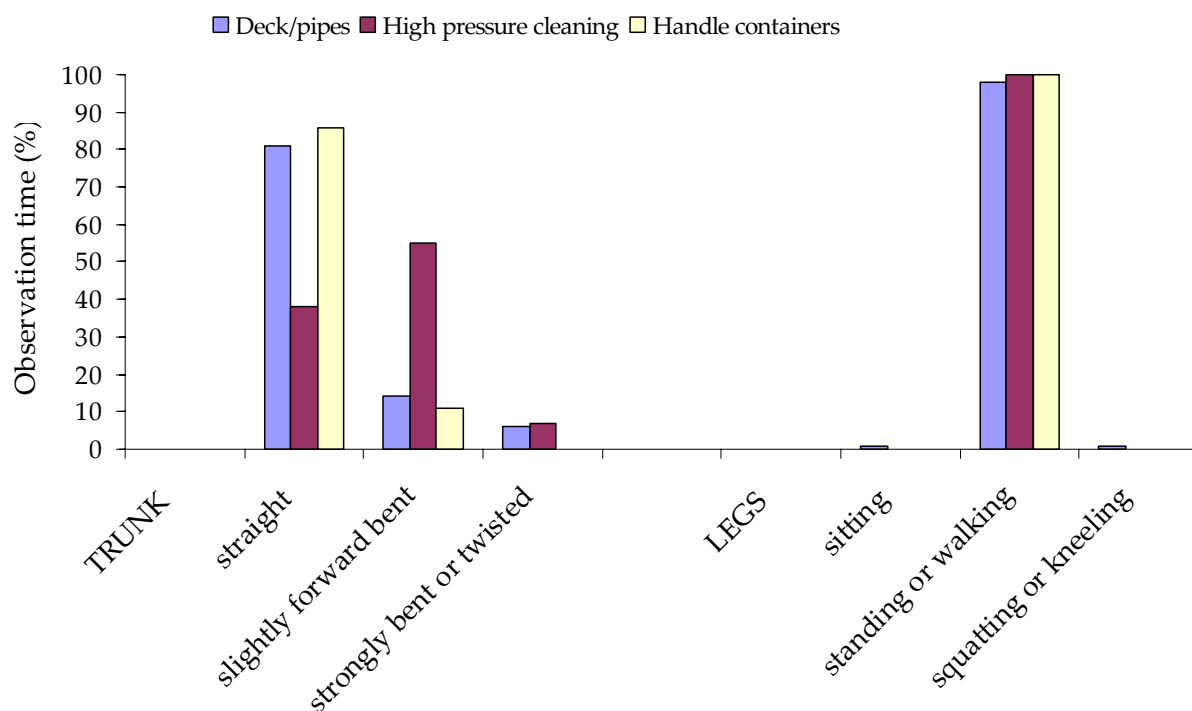


Fig. 3.10. Relative time spent in different trunk and leg postures

From an ergonomic viewpoint, roustabouts have good variation in their job. Relative time spent in different trunk postures reveal that 94% of the time they worked with the trunk in an upright or almost upright posture. The remaining 6% of the observed time they worked in more critical positions like strongly forward bent and laterally bent. During maintenance with a high-pressure cleaner the trunk was slightly to strongly forward bent for 50% of the time.

Primary risk factors like squatting or kneeling was seldom observed. The job of the roustabout was observed to be a combination of walking and standing. Prolonged standing can most of the time be avoided as the roustabouts in general were free to move around

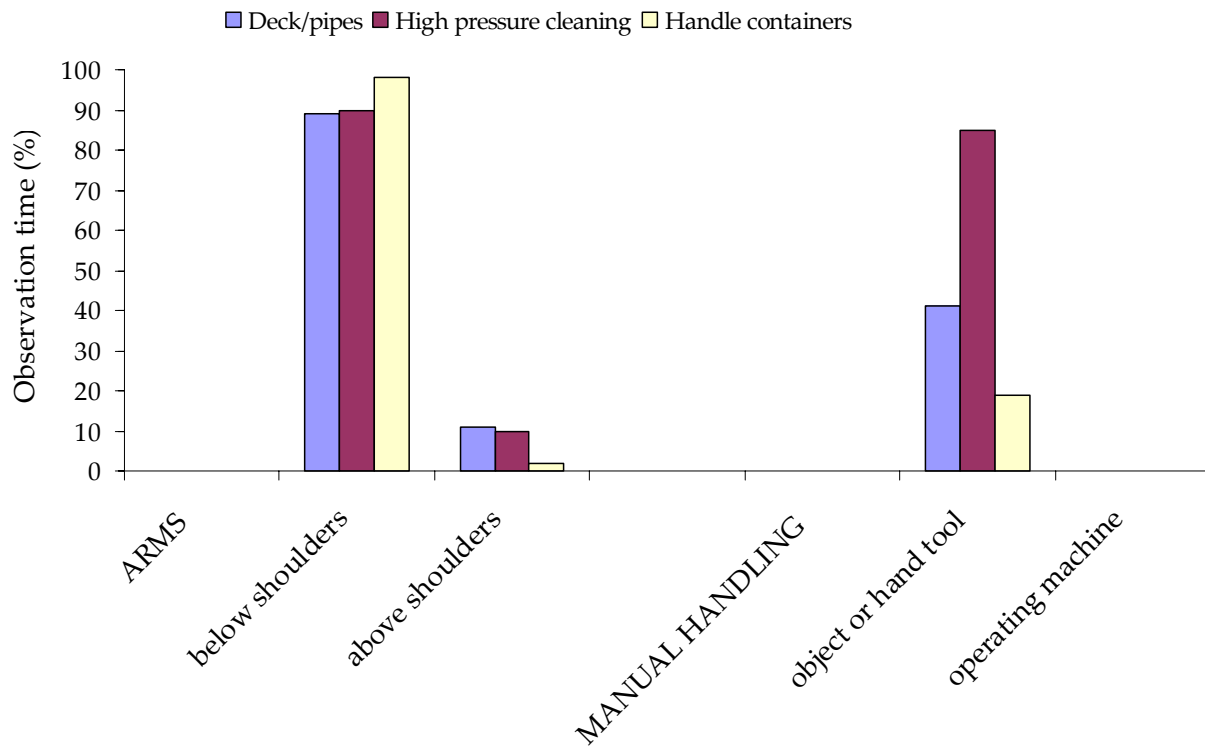


Fig. 3.11. Relative time spent in different arm postures and performing manual handling

Fig. 3.11 shows that 18-99% of the time is spent on manual handling of objects or hand tools and on average 56% of all subtasks include work with objects or hand tools. The force exertion during manual handling varied from light to very heavy.

Heavy force exertion was seen during slinging and handling of containers from supply vessels. Experience and communication with the crane operator seemed to be an important factor for smooth operation. To a lesser extent (10%) some medium to high exertion was observed during preparation of pipes. Considering the total working time, heavy object handling was performed for less than 5% of a 12 hours working day. The majority of the handled objects or hand tools operated did not exceed 10 kg.

3.4.2 Manual lifting

During days where pipes and casing are moved up and down from the drill floor the workers were repeatedly exposed to awkward postures and handling of heavy tools and material. Four photos in Fig. 3.12 summarize the situation, where the slip is lifted up to be locked on a pipe. Workers may be exposed to increased risks of musculoskeletal injuries depending on the actual weight of the slip. This may be illustrated with the lifting analyses presented in Table 3.2.

Table 3.2. Lifting equation values for roustabouts working with tubular handling on deck

Distance from body	Actual load (kg)	Recommended Weight Limit (kg)		Lifting index	
		Origin (catwalk)	Destination (locked on tubular)	Origin	Destination
Medium ^a	5 / 10 / 20 / 40	11.2	12.1	0.4 / 0.9 / 1.8 / 3.6	As origin
Near ^b	5 / 10 / 20 / 40	15.7	16.9	0.3 / 0.6 / 1.3 / 2.5	As origin
Far ^c	5 / 10 / 20 / 40	9.8	10.6	0.5 / 1.0 / 2.0 / 4.1	As origin

^a Slips lifted from deck to tubular (vertical distance 5 - 25 cm, strongly forward bent) Load 35 cm from feet

^b Slips lifted from deck to tubular (vertical distance 5 - 25 cm, strongly forward bent) Load 25 cm from feet.

^c Slips lifted from deck to tubular (vertical distance 5 - 25 cm, strongly forward bent) Load 40 cm from feet.

Three examples of “distance from the feet” were calculated to illustrate the differences between lifting near and further away from the body. However, the weight of the slip is most important for the risk of developing LBP. The LI indicated that loads exceeding about 15-20 kg are associated with an increased risk of developing LBP.



Fig. 3.12. Lay down and pickup tubular

3.4.3 Conclusions

Exposure to prolonged awkward postures was not a general problem for the roustabouts. Adequate variations of physical demands were observed, and therefore beneficial for both muscles and joints. However, heavy manual handling does occur and peak exertions of short duration were observed. In particular, solutions to pick up pipes and casing to the drill floor should be found as handling slips to pick up pipes probably is the work process, which imposes the highest risk of developing musculoskeletal problems for the roustabouts.

Awareness towards prolonged work with high pressure devices would be beneficial. Prolonged static work during maintenance (high pressure cleaning) can lead to soreness, fatigue and pain in arms and shoulder regions. Worsening factors include increased force exertion and hand vibrations.

3.4.4 Suggestions for improvement

- Technical improvements for picking up pipes and casing at the catwalk should be considered. It should be considered whether a crane for pipe handling could be installed or the slips weight can be reduced.
- High pressure cleaning should not exceed 10 – 12 % of workday (12,5 % = 1h in 8 hour working day and 8,5 % = 1 hour in 12h workday).

3.5 (Ass.) crane operator

Work area: Deck

Work task: Crane operation

A full analysis of the tasks performed by the assistant crane operator and the crane operator was not performed. We have paid attention to “operation of 5 ton crane” and some more general observations in relation to work in the main cranes.

3.5.1 Operating the 5 ton crane



Fig. 3.13. Remote operation of 5 ton crane

Fig. 3.13 shows a typical posture during 5 ton crane operations. The crewmember stands/walks below while the loads are handled with the crane high above deck level. In order to visually follow the swinging loads the crane operator bends his neck backwards.

3.5.2 Endeavour main crane

Visual limitations and inexperienced deck crew are potential stress factors for the crane operator. Ergonomically, all handles and pedals are placed within good reach. Top camera and the connected television (centre picture) did only provide limited view over the crane hook location and possibilities for adjustment in order to increase luminance on the television setup were limited (Fig. 3.14).



Fig. 3.14. Endeavour main crane

3.5.3 Suggestions for improvement

- Ass. crane operator: Awareness of the neck position during 5 ton crane operation could be encouraged. Furthermore, job rotation would be beneficial in order to prevent prolonged exposure. Maybe more people should be certified to operate the crane. Finally, whenever possible, the crewmember should seek a high work platform in order to look down instead of up when operating the crane.
- Crane operator: An upgrade of the camera and television would be beneficial in order to enhance picture quality.

3.6 SCO

Work area: Shaker room and cabin
 Work tasks: Surveillance and shaker maintenance

The SCO inspects and changes screens on the shakers that filter drilling mud, which is pumped up from the pipe hole.

For about 80% of the work time the SCO sits in his cabin surveying the shakers to ensure proper and continuous functioning of the filtering process. A few times during a work shift the SCO changes the shaker screens to clean them. No formal analyses were made of the work tasks due to the long periods with sedentary surveillance of the shakers, which was performed without physical activity. In contrast, changing shaker screens was performed with awkward postures, such as strongly forward or laterally bent trunk or squatting to unscrew and tighten the bolts that held the screens in place. The workspace was narrow between shakers, which should be considered when designing rigs. Possibly,

some improvements could be achieved by using tools with longer handles, both to avoid strongly bending and increase the lever arm to reduce the force needed to unscrew bolts. However, this is only possible, where space allows it. Thus, long term exposure to awkward postures was not present for the SCO, but force exertion while bending may increase the risk of developing musculoskeletal problems, even when the duration is short.



Fig. 3.15. The SCO tightens a bolt on the shaker

3.7 Steward, Cook and Camp boss

Work area: Catering

Work tasks: Cleaning of cabins/shower, making beds, laundry, galley and receiving goods

Catering activities are performed by stewards, cooks and the camp boss. The latter is the local manager of catering on the rig. These employees are employed by a subcontractor, not by Maersk Contractors. Each of the three job positions has specific tasks, but also tasks that are shared by two different job positions. Thus, cleaning of the accommodation area, making beds and doing the laundry is performed exclusively by the stewards, but the stewards also participate in activities in the galley together with the cook. Receiving stores in containers may be performed by all 3 job positions and cooking is done by cooks or the camp boss.

3.7.1 Postures and manual handling

Figures 3.16 and 3.17 show the time spent in different postures.

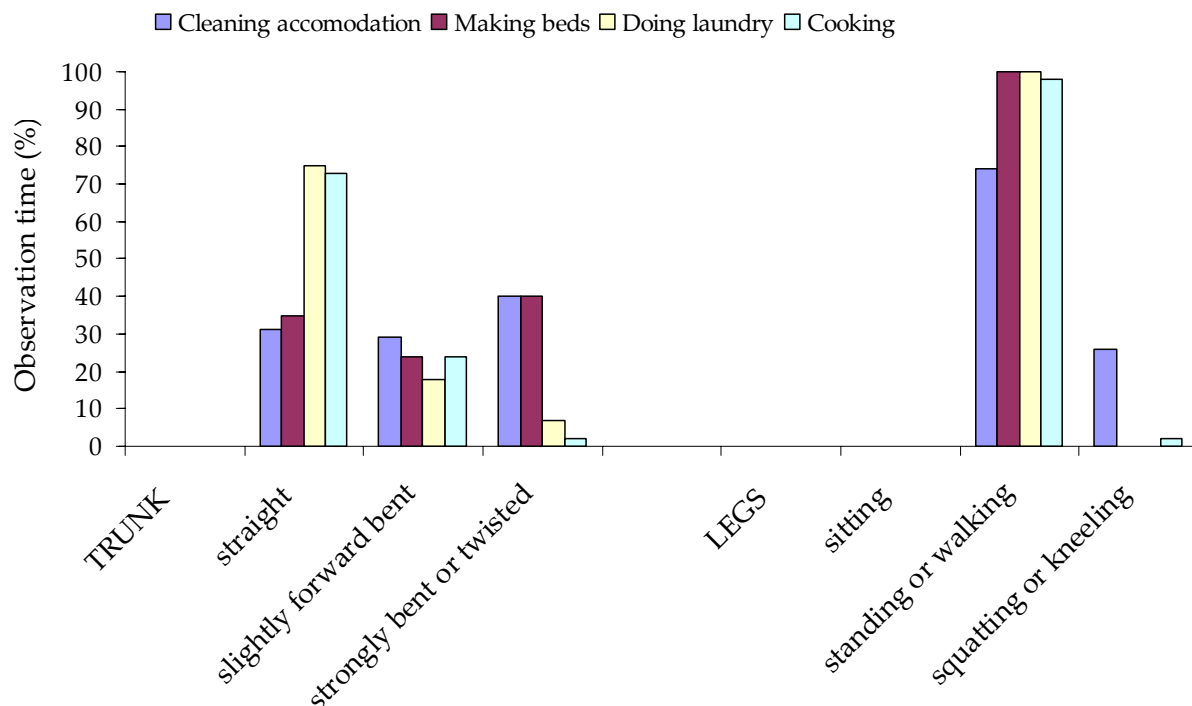


Fig. 3.16. Relative time spent in different trunk and leg postures

For catering personnel twisted, forward and laterally bent trunk postures were mainly observed during cleaning of the accommodation area and making beds, where about 40% of the time was spent in a strongly forward bent, laterally bent or twisted trunk posture. During cooking and when doing the laundry, work was performed in an upright posture for about 75% of the time. Elevated arms above shoulder height were observed for 31% and 21% of the work time during cleaning of the accommodation area and making beds,

respectively. During cooking this was only observed for 2% of the time and when doing laundry it was observed for 7% of the time.

Awkward leg postures during working are kneeling and squatting. Squatting was only observed during cleaning, but for a relatively large fraction of the time, approximately 25%. Otherwise, standing postures were mainly observed. Furthermore, cleaning above shelves and making the upper bed cannot be performed from the ground and a small staircase is used as a work platform.

Squatting or kneeling was seldom observed for the two cooks.

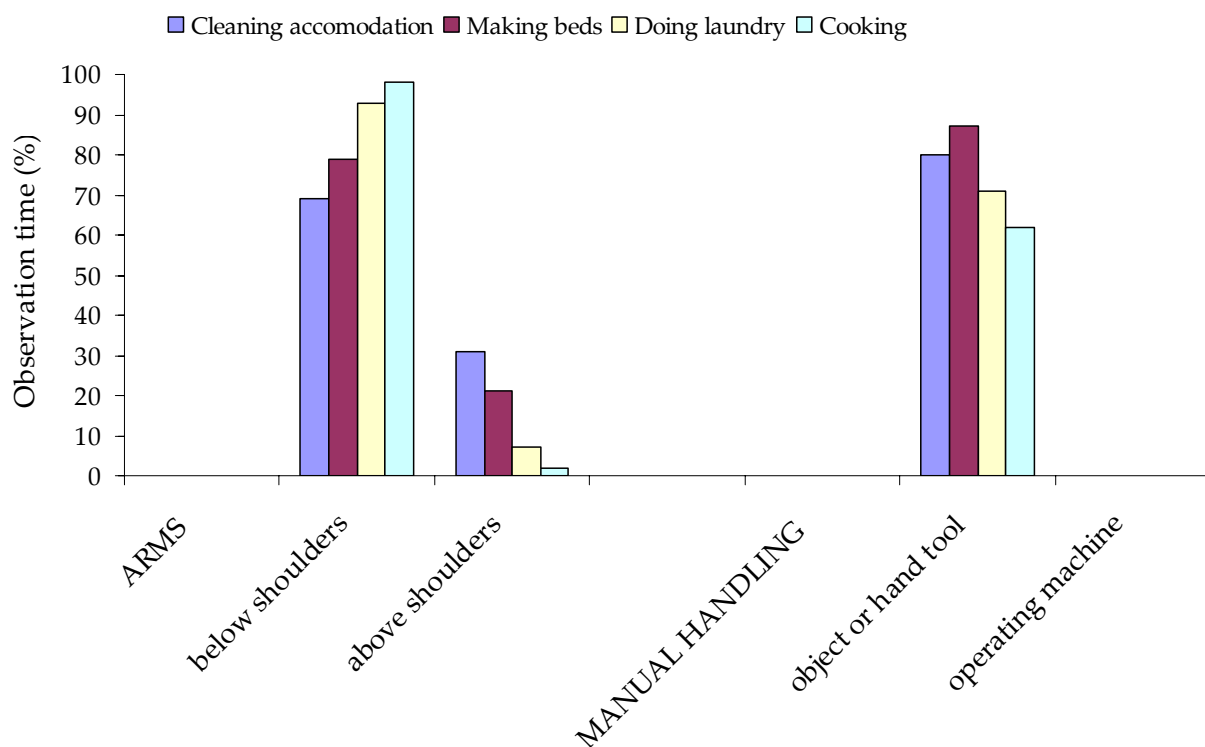


Fig. 3.17. Relative time spent in different arm postures and performing manual handling

Fig. 3.17 shows that 60-90% of the time the work tasks consists of lifting, carrying, pushing or pulling objects or hand tools. The force exertion was not high, as it was only seldom that objects weighed more than 3 kg.

However, when stores are received in containers, which take place once or twice during a two-week offshore period, heavier object are handled. Due to the fairly short duration of this task, this is analyzed separately with the NIOSH lifting equation.

A



B



Fig. 3.18. During cleaning of the accommodation awkward and strongly forward bent postures were observed. Strongly forward bent when making the beds (A). Using work platform for cleaning upper side of lockers (B).

A



B



C



D



Fig. 3.19. More examples of accommodation cleaning. (A) Squatting necessary to clean below beds. (B) Forward bent and hand tool operation for cleaning underneath table. (C) Squatting and one hand support needed due to limited space while cleaning the shower (D) Using work platform, forward bent with twist in order to reach top corner while making the beds.

3.7.2 Food containers

Boxes with food are delivered in containers, which are offloaded manually next to the galley. Once or twice during each offshore period 2-4 food containers need to be offloaded. Limited space below deck restricts the working space for crewmembers involved, especially inside the container. Onshore, these containers are loaded with forklifts, however, this is not possible on the rig. During offloading, from either the upper or lower section of the containers, the crewmembers are exposed to repetitive lifting in both forward and twisted postures. A summary of the results from NIOSH lifting calculations are provided in Table. Depending on the loads (8 - 16 kg) the lifting tasks pose a low risk

to high risk for lower back pain (LBP). In the table, origin in the first row refers to a situation where the goods are lifted from the midsection of the container. Destination refers to placing the goods on a table in the kitchen. From inside the container all loads lifted from the lower section exceeding 8 kg pose a high risk and the recommended load weight is 4.5 kg. All loads lifted from the upper section of the container exceeding 12 kg pose a high risk and recommended load is 5 kg.

Table 3.3. Lifting equation values for crew offloading food from containers in the kitchen. Different examples are given, where the actual load is varied from 8 to 16 kg.

	Actual load (kg)	Recommended Weight Limit (kg)		Lifting index (kg)	
		Origin (container)	Destination (table)	Origin	Destination
Raising ^a	8 / 10 / 12 / 16	4.5	10.0	1.8 / 2.2 / 2.7 / 3.6	0.8 / 1.0 / 1.2 / 1.6
Lowering ^b	8 / 10 / 12 / 16	5.0	10.6	1.6 / 1.9 / 2.2 / 3.0	0.7 / 0.9 / 1.1 / 1.5
Near ^c	8 / 10 / 12 / 16	11.1	As raising	0.7 / 0.9 / 1.1 / 1.4	As raising
Far ^d	8 / 10 / 12 / 16	3.7	As raising	2.2 / 2.7 / 3.2 / 4.3	As raising

^a Boxed load lifted from midsection of lower section to table in kitchen (vertical distance 20 cm to 110 cm)

^b Boxed load lifted from upper section to table in kitchen (vertical distance 180 cm to 110 cm)

^c Boxed load lifted from near end of lower section to table in kitchen (vertical distance 20 cm to 110 cm)..

^d Boxed load lifted from far end of lower section to table in kitchen (vertical distance 20 cm to 110 cm)..

In the observed case the weight of boxes was about 8 kg. The RWL was calculated to 4.5 kg. The actual load was above the recommended load limit and the lifting index was $8/4.5 = 1.8$ indicating a medium risk. The term “near” in the third row refers to a situation where the goods are wheeled outside the container or moved close to the front edge before lifting it. This reflects the best scenario, where lifting can then be performed more upright and near the body and the RWL is 11 kg.

In summary, offloading from the upper section results in a slightly better lifting situation compared to offloading from the lower section of the container. However, both situations pose a medium LBP risk. Worst case situation happens when offloading from the far end of the lower section. Best case situation occurs, when offloading can be done either outside the container or near the front edge of the container.

3.7.3 Conclusions

The posture analyses pointed towards cleaning of the accommodation area and making beds as the tasks, where awkward postures occur most frequently. Cleaning the cabins and other accommodation areas is performed with a relatively high duration of strongly forward bent or twisted trunk postures. Furthermore, squatting is often needed to clean properly under beds and tables. Making beds cannot be done without strongly bending the trunk; often standing on a platform. Limited work space implies that the use of awkward postures is frequent both when making the upper and lower beds. The total time spent by the stewards performing these tasks is considerable, i.e. estimated to have a

duration of more than 4 hours (cleaning) and between 1 and 4 hours (making beds) per shift. Cooking and doing the laundry are performed mainly with neutral body postures as extreme postures were observed to have a short duration. When doing the laundry most of the time is spent sorting and arranging clean clothes, which can be done in an upright posture. Putting clothes into washing machines and taking it out takes considerably less time. Thus, neutral postures are observed for most of the work time.

The galley is well designed with sufficient space between the different work stations, even though the sink next to the dish washer is not as easily accessible as it would be preferred. However, cooking is performed almost without any awkward postures.

Emptying food containers expose the crewmembers to medium and high risks of developing back problems unless loads are lifted outside or near the front edge of the container.

3.7.4 Suggestions for improvement

- It would shorten the duration of awkward postures, if cleaning under the beds could be avoided. The most effective solution would be to close the floor area below the bed.
- It would be an advantage to use top mattresses and stretch sheets on the beds. Thereby, the mattress could be taken out from the bed and new sheets could be put in place while standing on the floor in an upright posture.
- Flip tables could, when not loaded with the crews personal belongings, be flipped down and cleaning could be performed from a more upright posture.
- A system should be developed to improve the offloading of food containers. Various wheeled systems exist, but an alternative system probably involves arrangements with the company packing the containers onshore. At least, heavy loads should be placed near the door of the container



3.8 Total job exposure

Exposure profiles of individual work tasks are suited to point out tasks associated with different risk levels of developing musculoskeletal pain. However, the work related risk of developing pain or disorders for an individual is probably more associated with the total exposure of the job. Therefore, the job analyses of specific tasks were also used to estimate the total ergonomic exposure due to trunk, arm and leg postures associated with the following job positions: Derrick man, roustabout, floorhand, driller and steward. A much easier method is to use questionnaire responses to estimate this exposure. The critical question is whether questionnaire responses can be used to estimate ergonomic exposure in a reliable way. Therefore, we compared questionnaire responses with the observed exposures. A total of 51 employees answered the questionnaires representing almost all job positions. The questions on trunk, arm and leg postures in the questionnaire were identical to those used in the checklist of the job analyses. Based on all questionnaire responses relating to working postures for each individual we calculated a posture index modified from Hollmann et al. (1999). No specific risk levels have been associated with specific values of the index, and it should only be used to rank the job positions according to different exposures to awkward postures. It should be emphasized that responses to questions on lifting loads were not included, as this would have made it difficult to compare with the job analyses based on observations.

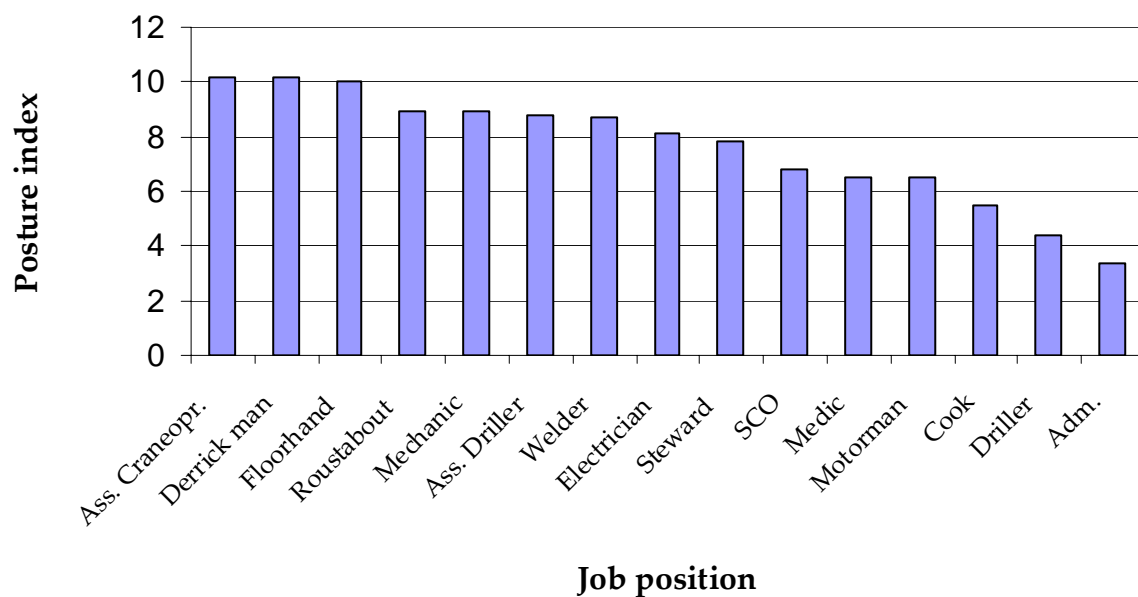


Fig. 3.20. Posture index based on questionnaire responses. High values indicate more exposure to awkward trunk, arm and leg postures.

The posture index values are shown in Fig. 3.20. As expected, job positions belonging to the administration were associated with the lowest index values and the highest index values were found for job positions belonging to the drilling and deck areas.

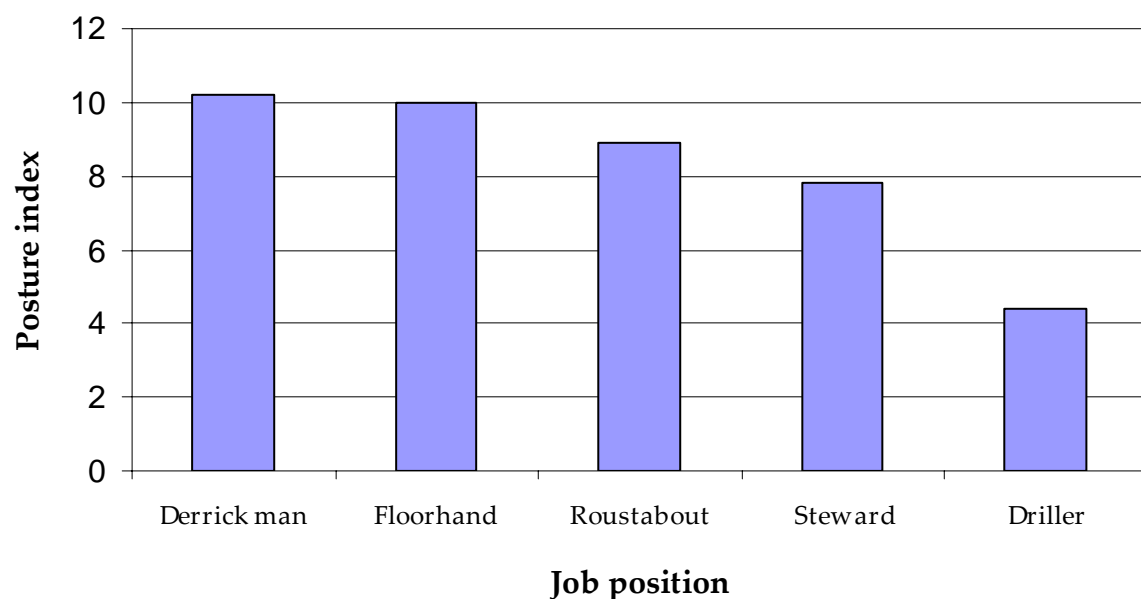


Fig. 3.21. Posture index based on questionnaire responses for five job positions. High values indicate more exposure to awkward trunk, arm and leg postures.

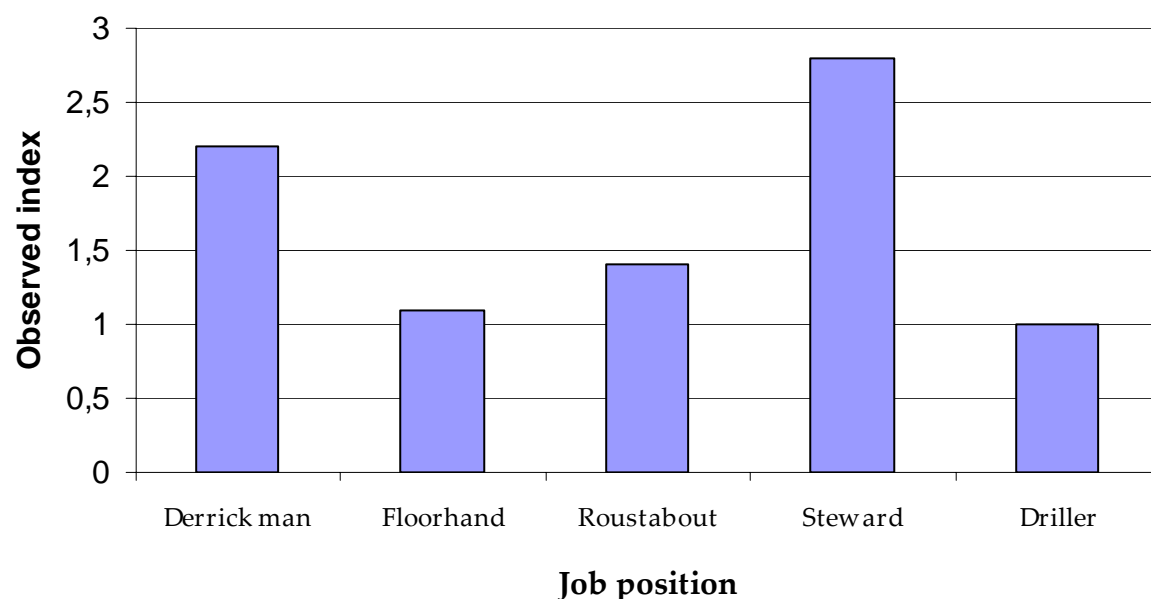


Fig. 3.22. Observed posture index based on job analyses for five job positions. High values indicate more exposure to awkward trunk, arm and leg postures.

The 5 job positions that were used for comparison with the results of the job analyses are presented also in Fig. 3.21. This shows that derrick men reported the most frequent exposure to awkward postures, whereas drillers reported the least frequent exposure to these postures. A similar index was calculated based on the observed exposures of specific tasks, which for each job position were averaged according to the time spent in each work task (Fig. 3.22). The index values of the two indices are not directly comparable, but the

ranking of the different job positions should be the same if both indices represent the real exposure. This was only partly the case. In both cases drillers showed the lowest values indicating that awkward trunk, arm and leg postures were not as frequent in this job position as in the others. However, the observations pointed towards stewards as the job position exposed to awkward postures more frequently than the other job positions. We believe that the index values based on observations reflect reality more than questionnaire responses, as ergonomic exposures are difficult to assess without direct observations or technical measurements.

The potential benefit of estimating the total exposure of job positions is that these exposures may be used in studies of the association between such exposures and musculoskeletal pain, disorders or sickness absence. Thereby, they may indicate how much sickness absence is due to exposures at work and how large the potential is for preventing ill-health and sickness absence through interventions at the work place. At present, we do not know how large this potential is.

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